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ESTABLISHMENT OF SHORT ROTATION FORAGE CROPS

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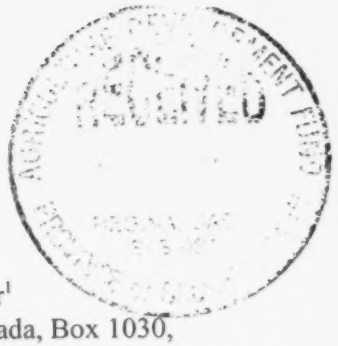

AgriFood Innovation Fund
Diversified Farming Systems Project Final Report
"Establishment of Short Rotation Forage Crops"
Project #97000385, Strategic Area 9.2

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(a) **Summary**

Short-lived perennial grass species with good seedling vigour could provide crop producers with a cash hay crop without requiring a year or more to become established. These "short rotation forage crops" must not only establish quickly and produce good forage yields but would also be a better fit in annual crop rotations if they could be seeded with a companion crop. Our objective was to determine the establishment and forage production of fast establishing forage grasses (Dahurian wildrye, intermediate wheatgrass, slender wheatgrass) as affected by soil zone, companion crop, and alfalfa associate (Beaver, Nitro (an annual alfalfa) or none).

Trials were established at Swift Current, Saskatoon and Nipawin in 1998, 1999, and 2000 with canola, pea, and annual ryegrass companion crops compared to no companion crop (control). In two out of three years at Nipawin (Black soil) companion crops had no detrimental effect on forage yield. In two out of three years at Saskatoon (Dark Brown soil) companion crops caused a reduction in forage yield. In all three years at Swift Current (Brown soil) companion crops reduced forage yield compared to control. The use of companion crops to establish short rotation forages should be recommended on a soil zone basis.

Spring weather in the establishment year was correlated with yield losses due to companion crops but the relationships varied among crops. As April and June monthly precipitation increased, yield loss due to canola declined. However, as May precipitation increased, forage yield loss after pea companion crop increased. For annual ryegrass companion crops, May, June and September precipitation were positively correlated to forage yield losses. Companion crop plant density and seed yield were positively related to losses after pea companion crops while companion crop biomass was negatively related to forage yield losses after annual ryegrass. These combinations of variables could predict forage yield (as percent of the control) with excellent regression coefficients ($r^2 = 0.9$, Prob.<0.01). It was previously believed that use of soil water by the companion crop resulted in death of forage seedlings under dry or semi-arid environments. However, forage seedling counts during the establishment year indicated only slight declines in forage seedlings due to companion crop competition, even at the driest environment. In fact, our data suggest that companion crops did not cause fewer forage seedlings but rather that they were smaller in size and less able to exhibit compensatory growth in the year

after establishment.

Intermediate wheatgrass had highest first cut forage yield at all three sites but produced less regrowth at second cut in Nipawin. Observations at Swift Current indicated that Dahurian wildrye persisted only two years while intermediate wheatgrass and slender wheatgrass persisted until the third year after establishment. Persistent grasses will be more difficult to control when seeding the next annual crop and this characteristic may be a significant agronomic advantage to Dahurian wildrye.

Beaver alfalfa-grass mixtures produced more forage than Nitro alfalfa-grass mixtures due to higher alfalfa plant density and its contribution to forage productivity. Nitro alfalfa exhibited some partial survival to the first year after establishment at most sites but it's overall plant density and contribution to forage yield was low and frequently nil. While forage quality was not monitored in this study, it is well-established that alfalfa contributes to significantly improved forage quality of mixtures. However, alfalfa can be difficult to control when seeding the next annual crop.

(b) **Technical Report**

Background and Objective:

An increase in the Saskatchewan beef cattle herd has occurred in recent years but there has been smaller increases in forage acreage. In addition, the drought of 2001 and 2002 has reduced forage supplies and increased the sale and movement of forages across the province. As a result, the cash value of hay is more widely recognized. Crop producers have realized that cash hay is a viable crop option for them in rotation with annual crops. However, traditional perennial forage crop species that are difficult to establish and left in for many years are not the best option for short rotations of forage and annual cash crops. Short-lived grass species that establish quickly and produce more forage for one to three years would provide traditional crop producers with a cash crop that would fit in their crop rotation system. Producers are concerned that the economic returns during the establishment year of forages are low and therefore, want to use companion crops to establish forages. Previous research at Swift Current has reported a significant decline in forage production when cereal companion crop establishment was used for dryland forages. In the Black soil zone of Saskatchewan, yield losses due to companion crop establishment were lower than those reported for Swift Current (Brown soil zone). These contrasting results among different soil zones within the province led to the conclusion that competition for limited soil water reduced forage seedling density in drier sites and made companion cropping much less viable. However, new annual crops, such as peas and canola, have not been tested as companion crops for establishment of grasses with high seedling vigour.

Dahurian wildrye is a short-lived bunchgrass developed from plant introductions from Central Asia and released in 1989. It is known to persist for three years in dryland seedings at Swift Current and was proposed for inter-seeding with Russian wildrye to improve the productivity of new pastures because Russian wildrye takes two years to become established. It has become more widely used in complex mixtures with other grasses and legumes to promote early stand establishment. Intermediate wheatgrass is a well-known forage grass that has been used for dryland forage seeding for more than 50 years. Results suggest that intermediate wheatgrass will persist for five years but some stands have been observed to last as long as ten years when managed conservatively. Slender wheatgrass is a native species often included in mixtures with other native grasses because it has excellent seedling vigour and stand establishment. Recent research at the University of Alberta has suggested that low seeding rates of slender wheatgrass should be used to keep it from becoming too competitive in the first few years after seeding it as part of complex mixtures.

The forage yield and quality advantages of including alfalfa in mixture with grasses is well-known and does not need repeating here. However, some producers are concerned about the bloat risk of too much alfalfa in a newly seeded forage stand and the cost of killing the alfalfa prior to the next annual crop. The excellent seedling vigour of alfalfa often produces grass-alfalfa mixtures that are dominated by alfalfa (more than 80% alfalfa in the first year after seeding). One alternative would be an annual or short-lived alfalfa cultivar based on non-winter

hardy germplasm. Nitro alfalfa from Minnesota is a non-winter hardy cultivar that was developed as an annual plow-down (or green manure) legume. It has shown some ability to survive one winter in Manitoba before succumbing to winter-kill during it's second winter. This characteristic could make it valuable in short rotation where alfalfa persistence is a problem. Manitoba research indicates that two herbicide treatments or four tillage operations are needed to kill winter-hardy alfalfa plants prior to seeding the next annual crop in the rotation sequence. If producers could get the forage production and forage quality benefits of alfalfa from a short-lived cultivar like Nitro and, at the same time, have less difficulty or cost in killing the alfalfa prior to seeding the next crop, then it could have significant agronomic advantages.

The objective of the project is to determine the establishment success (risk) and first year production of fast establishing forage grasses, Dahurian wildrye, intermediate wheatgrass, and slender wheatgrass, as affected by soil zone (Swift Current - Brown; Saskatoon - Dark Brown; Nipawin - Black), companion crop (canola, pea, annual ryegrass vs none) and alfalfa mixture (Beaver, Nitro or none).

Materials and Methods

Three sites were used for this study. The Semiarid Prairie Agricultural Research Centre (SPARC) of Agriculture and Agri-Food Canada (AAFC) site located described as "the South Farm" is a dryland site approximately 1.5 km southeast of the city of Swift Current, Saskatchewan. It is located in the Brown Soil zone. The Saskatchewan Forage Council obtained access to the AAFC Research Farm near Saskatoon for seeding trials there. It is located in the Dark Brown Soil zone. Newfields Seeds Ltd operates a research and demonstration farm at Nipawin. It is located in the Black Soil zone. The color of each soil zone indicates the level of natural organic matter, with Brown soil having the least organic matter and Black soil the most. The locations also represent a range of precipitation and water deficit during the growing season with Swift Current the driest and Nipawin the wettest environment.

A cereal crop stubble site was obtained at each location and sprayed with "Roundup" herbicide in early spring for pre-seeding weed control. The experimental design was a split-split plot with four replications. Companion crops were the main plot treatment, grass species were the sub-plot treatment, and alfalfa mixtures were the sub-sub-plot treatment. Row spacing was 30 cm but the companion crops and forages were seeded in separate rows so there was 15 cm between forage seedlings and the companion crop plants.

The seeding rates for the companion crops in lb ac^{-1} (followed by kg ha^{-1} in brackets) were: 135 (151) for 'Highlight' field pea (*Pisum sativum*), 4 (4.5) for 'Coronet' canola (*Brassica napus*), and 5 (5.6) for 'Aubade' westerwolds ryegrass (*Lolium westerwoldicum*). The forage crop seeding rates varied among the sites according to the provincial recommendations. At Swift Current, Saskatoon and Nipawin respectively, the seeding rates were: 4 (4.5), 7 (7.8), and11 (12.3) for 'Arthur' Dahurian wildrye (*Elymus dahuricus*) and 'Chief' intermediate wheatgrass

(*Agropyron intermedium*); 2 (2.2), 4 (4.5), and 6 (6.7) for 'Revenue' slender wheatgrass (*Agropyron trachycaulum*); and 2 (2.2), 2 (2.2) and 3 (3.4) for 'Beaver' and 'Nitro' alfalfa (*Medicago sativa*).

Prior to seeding, 34-17-0 (NPK) fertilizer was applied at 150 lb ac^{-1} or 168 kg ha^{-1} to supply 50 kg N ha^{-1} and 35 kg P ha^{-1}. In addition, all alfalfa seed was inoculated with appropriate Rhizobium inoculant prior to seeding. N fertilizer application at 70 lb ac^{-1} or 77 kg ha^{-1} and K fertilizer at 10 lb ac^{-1} or 11 kg ha^{-1} was applied in October 1998 at Nipawin. No fertilizer was applied in the year after establishment. This is a common practice among forage producers because young fields of forage crops are generally considered to be using residual fertility and do not respond to additional fertilizer until 3 or more years after establishment.

The seeding dates were: 13 May 1998, 19 and 20 May 1999, 18 May 2000 at Swift Current; 01 June 1998, 25 May 1999 and 21 June 2000 at Saskatoon; 19 May 1998; 20 May 1999 and 01 June 2000 at Nipawin. Seeding depth of forage and canola seeds was maintained at 19 mm (0.75 in) but peas were seeded at 75 mm (3 in) depth.

At all three sites, no additional herbicides were used for weed control in the establishment year. Herbicides were applied for weed control in the established forage stands (one year after establishment) at Saskatoon. Pardner (bromoxynil) was sprayed at 0.5 L ac^{-1} in 1999, 2000 and 2001 with an additional application in 2000. In 1999, an application of Cobutox (2,4-DB) at 0.73 L ac^{-1} was also applied. At Nipawin, Pardner at 0.4 L ac^{-1} was applied once in the established forage stands in the spring. In 1999 at Nipawin, spray drift from an adjacent trial resulted in the loss of the canola companion crop prior to maturity. No herbicides were used at Swift Current in the year following establishment.

Companion crop plant and forage seedling densities were determined by counting plant numbers in two row segments (1 m length) in each plot at 4, 8, and 12 weeks after seeding. Seedling densities differed among companion crops and forage species but rank order did not change from one count to the next so plant or seedling densities were averaged over all three dates. Forage plant counts were determined in a similar manner in the spring following the establishment year.

Companion crop forage yield (control, annual ryegrass) or seed yield (canola, peas) was determined at maturity for each site. Forage from no companion crop treatment was harvested on: 07 August 1998, 25 August 1999, and 16 August 2000 at Swift Current; 21 July 1998, 27 August 1999, and 11 September 2000 in Saskatoon; 14 August 1998, 27 August 1999 and 23 August 2000 at Nipawin. Forage from annual ryegrass companion crop was harvested on: 06 August 1998, 24 August 1999, and 14 August 2000 at Swift Current; 21 July 1998, 27 August 1999, and 11 September 2000 in Saskatoon; 14 August 1998, 27 August 1999 and 23 August 2000 at Nipawin. Seed yield of canola companion crop was determined on: 05 August 1998, 20 August 1999, and 14 August 2000 at Swift Current; 21 July 1998 13 September 1999, 11 September 2000 at Saskatoon; 14 August 1998, 09 September 1999 and 24 August 2000 at Nipawin. Seed yield on pea companion crops was determined on: 04 August 1998, 19 August

1999, and 11 August 2000 at Swift Current; 21 July 1998 13 September 1999, 11 September 2000 at Saskatoon; 14 August 1998, 27 August 1999 and 24 August 2000 at Nipawin.

Forage yield was determined at approximately 10% flowering stage of the alfalfa during the year following establishment at all three sites for each trial. The forage harvesting dates were: 10 July and 02 September 1999, 27 July and 25 August 2000 and 03 July, 12 August and 11 September 2001 at Nipawin; 24 June and 27 August 1999, 27 June 2000, and 21 June 2001 at Saskatoon; and 15 June 1999, 24 July 2000, and 25 July 2001 at Swift Current. Forage material was harvested from the centre of each plot and weighed. A sub-sample of forage was weighed, dried to constant weight and re-weighed to determine dry matter percentage. Dry matter forage yields were calculated for each plot.

Analysis of variance of a split-split-plot design was calculated with JMP software (SAS Institute Inc. Cary NC). Few three-factor or two-factor interactions were statistically significant (see ANOVA tables in Appendix) so the means of main factors are presented in tabular form.

Daily weather data was obtained from nearby stations reporting to Environment Canada. The data were obtained from Eastern Cereals and Oilseeds Research Centre of AAFC who in turn had obtained it from Meteorological Service of Canada (Environment Canada). Monthly mean temperature, precipitation and potential evapo-transpiration were calculated for each site-year combination. Companion crop plant density, biomass and seed yield were also calculated for each site-year combination.

Forward stepwise regression of JMP software was used to relate weather and companion crop variables to forage yield loss (% of no companion crop treatment). Variables were selected for inclusion in the procedure at P=0.25 and excluded at P=0.10. Due to different growth forms and periods among the three companion crops, a regression equation was calculated for each companion crop.

Economic analysis was conducted by totaling all costs from the establishment year and the first forage production year (2 year costs) and all revenues from crops produced in the establishment year and the first forage production year. Costs were based on actual fertilizer and herbicides applied at each site. Other costs were based on custom field work rates for seeding and harvesting operations. Net returns for the two year period were calculated from these costs and returns. Hay price was adjusted for three price levels in the analysis, $75, $100, and $125 per ton of hay. The lowest hay price reflects the long-term price of alfalfa hay in Saskatchewan in years of abundant forage supply. The highest price reflects our estimate of price level observed in years of forage shortages. During the winter of 2001-2002, hay prices at Swift Current hit $140 per ton. We noted that these three prices reflect a reasonable range of low, medium, and high hay prices for the purpose of our analysis.

Results and Discussion

Companion Crops

Companion crops reduced subsequent forage yield at Nipawin in 2001, Saskatoon in 1999 and 2000, and in Swift Current from 1999 to 2001 (Table 1). At Nipawin in 2001, companion crops reduced forage yield by 29%. At Saskatoon in 1999 and 2000, companion crops reduced forage yield by 37%. At Swift Current, companion crops reduced forage yield by an average of 39% over three years. Based on both the probability of a significant effect of companion crop and the magnitude of the effect, the impact of companion crops on forage yield at the three sites can be ranked. The impact is greatest at Swift Current and least at Nipawin.

Differences among the three companion crops were not consistent (Table 1). At Saskatoon 1999 and Nipawin 2001, the effect of annual ryegrass on forage yield was greater than that of canola or pea. At Saskatoon in 2000, the effect of pea was greater than that of canola or annual ryegrass. At Swift Current in 2000, the effect of canola was greater than that of pea or annual ryegrass. At two other site-years, the effect of the three companion crops were similar.

There was a significant correlation between forage seedling plant density and forage yield at each site (Fig. 1). The highest plant density and biggest forage yield occurred for no companion crop stands at all three sites. As plant density decreased with companion crop establishment, there was a reduction in forage yield. However, the slope of the relationship varied among sites, with a shallow slope at Nipawin and a steep slope at Swift Current. In other words, a large decline in plant density at Nipawin resulted in a small decline in forage yield while at Swift Current, a small decline in plant density resulted in a large decline in forage yield.

It was previously believed that companion crop competition reduces forage seedling survival during the establishment year and that these thinner stands are less productive in subsequent years. These results suggest that other yield components, such as leaf number or size, tiller size or height of reproductive tillers or the ratio of reproductive tillers to vegetative tillers may explain the yield decline due to companion crop competition.

The results of this project clearly show that impacts of companion crop forage establishment varies across the soil zones of Saskatchewan. Producers in the Black soil zone can choose to use companion crops to establish these grasses with a 1 in 3 chance of slightly reduced forage yield. Producers in the Brown soil zone should not use companion crops to establish these grasses due to the consistent and large reductions in subsequent forage yield.

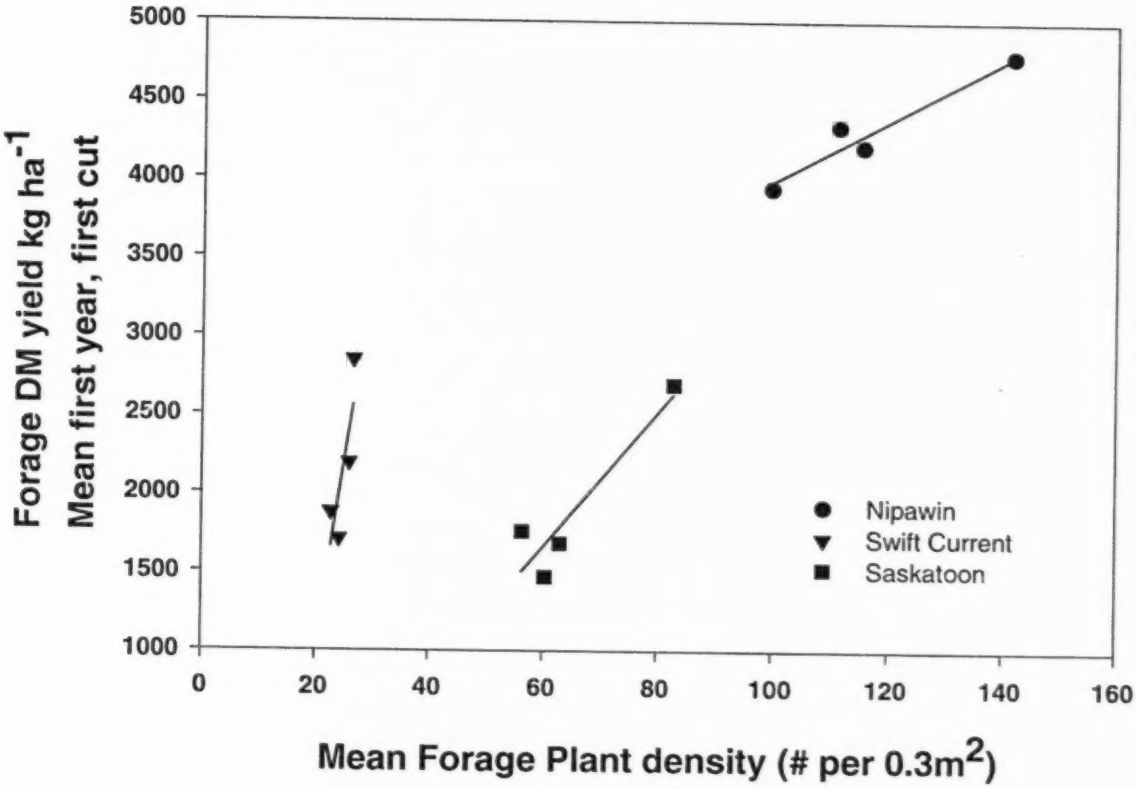
Table 1. Effect of companion crop in the previous year on forage DM yield at cut 1 and cut 2 for three sites in Saskatchewan from 1999 to 2001 (cut 2 was harvested only when regrowth was sufficient).

			Companion Crop in establishment year					
Year	Harvest	Site	None	Canola	Pea	Ryegrass	Prob.> F	SE [y]
1999	Cut 1	Nipawin	6732	6463	6396	6588	ns [z]	--
		Saskatoon	5149	4187	4172	3116	*	448
		Swift Current	1239	820	725	923	**	109
	Cut 2	Nipawin	1454	1303	1531	1584	ns	--
		Saskatoon	2573	2413	2260	2354	ns	--
2000	Cut 1	Nipawin	2489	2444	2451	2160	ns	--
		Saskatoon	2790	1766	1072	1511	***	258
		Swift Current	5057	2557	3329	3363	***	217
	Cut 2	Nipawin	2182	2429	1921	2197	ns	--
2001	Cut 1	Nipawin	5124	4096	3775	3077	***	255
		Saskatoon	601	624	387	496	ns	--
		Swift Current	1771	1030	987	988	***	61
	Cut 2	Nipawin	3905	3399	4034	2973	***	143

[z] ns- not significant; *, **, and *** indicate probability values 0.05, 0.01, and 0.001, respectively.
[y] SE - Standard error

Figure 1.

Effect of companion crop on forage seedling density and its relationship to forage DM yield at three sites in Saskatchewan.



Companion crop effects and weather

Variation among site-years for weather and companion crop variables accounted for 94, 91 and 90% of the variation in forage yield loss due to canola, pea, and annual ryegrass companion crops, respectively (Table 2). Spring rainfall was consistently selected for all three regression equations. However the coefficients for rainfall varied between canola and pea or ryegrass.

As April and June rainfall and June evaporation increases for canola, the forage yield loss declines. The June period coincides with the flowering period for canola.

As May, June, and September rainfall increased for annual ryegrass, forage yield losses increased. The annual ryegrass exhibited regrowth after forage harvest during the establishment year. September rainfall would result in more regrowth and continued competition for soil water between the annual ryegrass companion crop and forage seedlings. Any environmental factor that increased the growth of annual ryegrass would contribute to reduced forage seedling establishment.

As May rainfall increased for peas, forage yield losses increased. This is similar to annual ryegrass but in contrast to relationships for canola. Forage yield losses after peas or annual ryegrass also were affected by companion crop variables such as plant density, biomass, or seed yield. We can conclude from these relationships that canola can be used as a companion crop for forage establishment in regions with cool spring temperatures and reliable spring rain. Peas can used where spring rainfall and low summer temperatures are common.

It is impossible to test the predictions developed in the stepwise regression approach since all nine site-years were used to develop the equations and cannot be used for validation purposes. However, we can conclude that weather/climatic conditions will control the risk of using companion crops to establish new forage stands.

Table 2. Results of stepwise regression analysis of the relationship between forage yield loss due to canola, pea, or annual ryegrass companion crops at three sites for three years in Saskatchewan.

Companion Crop	% Forage yield loss =	R^2 statistic
Canola	435.1 - 0.52(Aprppt) - 0.70(Junppt) - 3.00(JunPE)	0.944**
Pea	0.53(Mayppt) + 8.58(JulTmn) + 1.03(CCdensity) - 0.01(CCseed) - 153.14	0.906**
Ryegrass	0.34(Mayppt) + 0.18(Junppt) + 0.62(Sepppt) - 0.01(CCbiomass) + 2.04	0.902**

% Forage yield loss was calculated as the difference between yield established with no companion crop and those established with canola, pea, or ryegrass companion crops expressed as a percent of the no companion crop yield.
**, * significant at P<0.01 and 0.05, respectively
Variables are: Aprppt = precipitation in April (mm); Mayppt = precipitation in May (mm);Junppt = precipitation in June (mm); JulTmn = mean July temperature (°C); JunPE = potential evapo-transpiration in June (mm); CCdensity = Companion crop plant density (# per 0.3 m^2); CCseed = Companion crop seed yield (kg ha^{-1}); CCbiomass = Companion crop biomass (kg ha^{-1}) .

Grasses

Intermediate wheatgrass produced the highest forage yield at first cut in all nine site-years (Table 3). It's regrowth (cut 2) forage yield was less than Dahurian wildrye or slender wheatgrass at three of four site-years for second cut. We conclude that intermediate wheatgrass is the best choice for short-rotation forage crops due to its yield advantage over the other two species.

A significant companion crop x grass species interaction occurred in 3 site-years (Table 17 in Appendix) out of 9 site-years. No companion crop treatment resulted in highest forage yield of all three grasses. The interaction resulted from rank order change of forage production for the other three companion-crop-established treatments.

Table 3. Effect of grass species on forage DM yield (kg ha^{-1}) from 1999 to 2001 at three sites in Saskatchewan.

			Grass Species				
Year	Harvest	Site	Dahurian Wildrye	Intermediate Wheatgrass	Slender Wheatgrass	Prob.>F [z]	SE [y]
1999	Cut 1	Nipawin	5730	7340	6570	***	351
		Saskatoon	3980	4410	4080	*	155
		Swift Current	660	1270	850	***	75
	Cut 2	Nipawin	1520	1530	1350	ns	--
		Saskatoon	2600	1960	2640	***	78
2000	Cut 1	Nipawin	2240	2840	2070	***	154
		Saskatoon	1840	2100	1420	***	102
		Swift Current	3490	3910	3330	***	130
	Cut 2	Nipawin	2330	2050	2108	*	92
2001	Cut 1	Nipawin	3910	4370	3770	*	195
		Saskatoon	540	610	440	**	40
		Swift Current	910	1640	1040	***	63
	Cut 2	Nipawin	3800	3370	3560	*	161

[z] ns- not significant; *, **, and *** indicate probability values 0.05, 0.01, and 0.001, respectively.
[y] SE - Standard error

Alfalfa cultivars

Alfalfa cultivar significantly affected first cut forage yield at Saskatoon and Swift Current but not at Nipawin (Table 4). Beaver alfalfa mixtures consistently produced more first cut forage yield than Nitro alfalfa. In several cases, Nitro alfalfa mixtures produced similar forage yield to grass alone. At second harvest, Nitro alfalfa mixtures produced more forage than grass alone in two site-years. Stand counts indicated that few Nitro alfalfa plants survived after the establishment year. A useful short-rotation alfalfa cultivar would survive for 1 to 2 years after establishment and contribute to forage production in a manner similar to Beaver alfalfa, then its plants would die prior to the next crop. Neither Beaver nor Nitro alfalfa appear to fit this need.

Table 4. Effect of alfalfa cultivar on forage DM yield (kg ha^{-1}) at two cuts from 1999 to 2001 at three sites.

			Alfalfa cultivar				
Year	Variable	Site	Beaver	Nitro	None	Prob.>F [z]	SE [y]
1999	Cut 1	Nipawin	6580	6050	6480	ns	--
		Saskatoon	5080	3460	3930	***	183
		Swift Current	1310	630	840	***	81
	Cut 2	Nipawin	2020	1170	1220	***	101
		Saskatoon	3520	2080	1610	***	95
2000	Cut 1	Nipawin	2310	2380	2470	ns	--
		Saskatoon	1820	1550	1980	***	62
		Swift Current	4300	3320	3100	***	123
	Cut 2	Nipawin	2420	2140	2000	ns	--
2001	Cut 1	Nipawin	3940	3970	4150	ns	--
		Saskatoon	720	470	380	**	35
		Swift Current	1220	1075	1287	***	36
	Cut 2	Nipawin	4400	3410	2920	***	130

[z] ns- not significant; *, **, and *** indicate probability values 0.05, 0.01, and 0.001, respectively.
[y] SE - Standard error

There was a significant companion crop and alfalfa cultivar interaction for six site-years at first cut (Table 18 in Appendix) and two site-years at second cut (Table 19). The interaction can be attributed to rank order changes in forage yield among the three companion crops.

Economic net returns

Net returns were better with no companion crop at Brown soil zone and Dark Brown soil zone sites (Table 5). At the Black soil zone site, net returns were similar with or without companion crop establishment. Producers frequently cite better net returns in the establishment year from companion crops as the primary reason to use this technique in forage establishment. However, by extending the economic analysis into the second year to account for losses in forage yield, we can conclude that the best economic returns are produced without companion crops at Brown soil zone and Dark Brown soil zone sites.

Table 5. Two-year production mean costs and net returns for companion crops by soil zone.

		Forage Price		
Companion Crop	**Total Cost**	**Low**	**Medium**	**High**
Brown Soil Zone	---------- ($/ha) -------- ----------			
None	379	92	250	407
Canola	358	71	118	164
Pea	447	80	133	187
Westerwold	404	1	136	271
Dark Brown Soil Zone				
None	481	54	232	410
Canola	471	-52	42	137
Pea	523	-161	-77	6
Westerwold	498	-60	86	232
Black Soil Zone				
None	603	306	609	912
Canola	608	474	686	898
Pea	685	342	554	766
Westerwold	664	317	643	971

The effect of grass species selection on two-year costs net returns was not consistent (Table 6). At the Brown and Black soil zone sites, intermediate wheatgrass produced the best economic returns while slender wheatgrass produced the best economic returns at the Dark Brown soil zone site.

Table 6. Two-year production costs and net returns for grass species by soil zone.

		Forage Price		
Grass Species/site	**Total Cost**	**Low**	**Medium**	**High**
Brown Soil Zone	---------- ($/ha) ----------			
Dahurian wildrye	401	51	147	242
Intermediate wheatgrass	404	79	186	292
Slender wheatgrass	386	53	146	238
Dark Brown Soil Zone				
Dahurian wildrye	503	-66	60	187
Intermediate wheatgrass	493	-56	70	195
Slender wheatgrass	484	-42	83	207
Black Soil Zone				
Dahurian wildrye	647	317	573	828
Intermediate wheatgrass	649	398	670	943
Slender wheatgrass	624	364	626	889

Grass plus Beaver alfalfa mixtures produced the best economic net returns at all three soil zone sites (Table 7). Beaver alfalfa was persistent in all site-years but Nitro alfalfa exhibited few plants that lived after the seeding year. This was consistent with the forage productivity of this mixture compared to grass plus Nitro alfalfa or grass alone mixture treatments.

Table 7. Two-year production costs and net returns for grass-legume mixtures by soil zone (meaned over all other factors).

		Forage Price		
Alfalfa cultivar in mixture /site	**Total Cost**	**Low**	**Medium**	**High**
Brown Soil Zone	---------- ($/ha) ----------			
Grass - Beaver	412	80	189	298
Grass - Nitro	400	40	134	227
Grass alone	380	64	155	247
Dark Brown Soil Zone				
Grass - Beaver	523	-14	136	285
Grass - Nitro	495	-92	21	135
Grass alone	462	-58	55	169
Black Soil Zone				
Grass - Beaver	671	388	667	947
Grass - Nitro	649	315	570	824
Grass alone	600	376	632	889

Appendix Tables

Table 8. Probability values from ANOVA of data from Nipawin trial seeded in1998.

	Establishment Year					1st Production Year				
			Companion Crop			Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield					
	Alfalfa	Grass				Alfalfa	Grass	Cut 1	Cut 2	Total
Replication	NS	NS	NS	NS	NS	0.04	<0.01	NS	NS	NS
Companion Crop	NS	NS	NS	NS	NS	NS	<0.01	NS	NS	NS
Grass (G)	NS	NS	NS	0.03	NS	NS	<0.01	<0.01	NS	<0.01
CC x G	NS	NS	0.02	NS	NS	NS	NS	NS	NS	NS
Alfalfa (A)	<0.01	0.01	NS	NS	NS	<0.01	<0.01	NS	<0.01	<0.01
CC x A	<0.01	<0.01	NS	NS	NS	0.05	NS	NS	0.06	NS
G x A	NS	NS	NS	NS	NS	NS	0.07	NS	NS	NS
CC x G x A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
c.v. (%)	47.3	25.0	28.8	37.2	17.4	95.9	25.4	19.2	33.5	16.9

Table 9. Probability values from ANOVA of data from Saskatoon trial seeded in1998.

	Establishment Year					1st Production Year				
	Companion Crop					Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield	Alfalfa	Grass	Cut 1	Cut 2	Total
	Alfalfa	Grass								
Replication	NS	0.07	0.08	NS	NS	0.05	0.01	0.01	<0.01	<0.01
Companion Crop	<0.01	<0.01	<0.01	<0.01	<0.01	0.04	NS	0.01	NS	<0.01
Grass (G)	NS	0.01	NS	NS	NS	NS	0.09	0.03	<0.01	NS
CC x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Alfalfa (A)	<0.01	NS	NS	NS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
CC x A	0.03	NS	NS	NS	NS	0.04	NS	<0.01	<0.01	<0.01
G x A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CC x G x A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
c.v. (%)	32.3	29.1	18.4	38.5	22.7	46.9	30.9	18.6	16.8	14.9

Table 10. Probability values from ANOVA of data from Swift Current trial seeded in1998.

	Establishment Year					1st Production Year				
	Companion Crop					Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield	Alfalfa	Grass	Cut 1	Cut 2	Total
	Alfalfa	Grass								
Replication	NS	NS	NS	NS	NS	0.01	NS	NS	NA	NA
Companion Crop	0.06	NS	<0.01	<0.01	<0.01	NS	0.02	0.01		
Grass (G)	NS	<0.01	NS	NS	NS	NS	<0.01	<0.01		
CC x G	NS	NS	NS	NS	NS	NS	NS	NS		
Alfalfa (A)	<0.01	0.05	NS	NS	NS	<0.01	<0.01	<0.01		
CC x A	NS	NS	NS	NS	NS	NS	<0.01	NS		
G x A	NS	0.03	<0.01	NS	NS	NS	0.07	0.06		
CC x G x A	NS	NS	<0.01	NS	NS	NS	NS	NS		
c.v. (%)	44.0	23.1	41.9	27.7	17.8	105.4	32.3	36.9		

Table 11. Probability values from ANOVA of data from Nipawin trial seeded in1999.

	Establishment Year					1st Production Year				
			Companion Crop			Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield					
	Alfalfa	Grass				Alfalfa	Grass	Cut 1	Cut 2	Total
Replication	0.01	NS	NS	NA	0.02	<0.01	NS	NS	0.02	0.07
Companion Crop	0.07	0.01	<0.01		0.04	NS	0.06	NS	NS	NS
Grass (G)	NS	<0.01	NS		NS	NS	<0.01	<0.01	0.02	<0.01
CC x G	NS	NS	NS		NS	NS	NS	NS	NS	NS
Alfalfa (A)	<0.01	0.02	NS		NS	<0.01	NS	NS	<0.01	NS
CC x A	0.03	NS	0.05		NS	NS	NS	NS	NS	NS
G x A	NS	NS	NS		NS	NS	NS	NS	NS	NS
CC x G x A	NS	NS	NS		NS	NS	NS	NS	NS	NS
c.v. (%)	36.2	13.3	25.8		39.6	105.9	25.9	18.6	20.2	14.4

Table 12. Probability values from ANOVA of data from Saskatoon trial seeded in 1999.

	Establishment Year					1st Production Year				
	Companion Crop					Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield	Alfalfa	Grass	Cut 1	Cut 2	Total
	Alfalfa	Grass								
Replication	NS	NS	NS	NS	NS	<0.01	NS	NS	NA	NA
Companion Crop	0.05	0.05	<0.01	NS	<0.01	NS	NS	<0.01		
Grass (G)	NS	<0.01	NS	NS	NS	NS	<0.01	<0.01		
CC x G	NS	0.02	NS	NS	NS	NS	NS	0.04		
Alfalfa (A)	<0.01	NS	NS	NS	0.03	<0.01	NS	<0.01		
CC x A	NS	NS	NS	NS	<0.01	NS	NS	<0.01		
G x A	NS	NS	NS	NS	NS	NS	NS	NS		
CC x G x A	NS	NS	NS	NS	NS	NS	NS	NS		
c.v. (%)	32.1	30.3	16.9	28.7	21.5	43.2	36.7	17.0		

Table 13. Probability values from ANOVA of data from Swift Current trial seeded in 1999.

	Establishment Year					1st Production Year				
	Companion Crop					Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield	Alfalfa	Grass	Cut 1	Cut 2	Total
	Alfalfa	Grass								
Replication	0.08	NS	NS	NS	NS	0.09	NS	NS	NA	NA
Companion Crop	<0.01	NS	<0.01	<0.01	<0.01	0.03	0.08	<0.01		
Grass (G)	NS	<0.01	NS	NS	NS	NS	<0.01	<0.01		
CC x G	NS	NS	NS	NS	NS	0.07	NS	<0.01		
Alfalfa (A)	<0.01	0.04	NS	NS	NS	<0.01	<0.01	<0.01		
CC x A	<0.01	0.08	NS	NS	NS	NS	NS	<0.01		
G x A	NS	NS	NS	NS	NS	0.03	NS	0.05		
CC x G x A	NS	NS	NS	NS	NS	NS	NS	NS		
c.v. (%)	37.1	19.7	14.0	10.0	11.1	37.3	51.9	16.9		

Table 14. Probability values from ANOVA of data from Nipawin trial seeded in 2000.

	Establishment Year					1st Production Year				
	Companion Crop					Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield					
	Alfalfa	Grass				Alfalfa	Grass	Cut 1	Cut 2	Total
Replication	<0.01	NS	NS	NS	NS	0.04	NS	0.04	<0.01	<0.01
Companion Crop	NS	<0.01	<0.01	0.09	<0.01	NS	NS	<0.01	<0.01	<0.01
Grass (G)	NS	0.04	NS	0.02	NS	NS	0.03	0.01	0.05	NS
CC x G	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Alfalfa (A)	<0.01	<0.01	NS	NS	0.08	<0.01	NS	NS	<0.01	<0.01
CC x A	NS	NS	NS	NS	NS	NS	NS	0.02	<0.01	NS
G x A	NS	NS	NS	NS	NS	NS	NS	0.05	NS	NS
CC x G x A	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
c.v. (%)	32.8	16.5	20.8	32.5	12.7	83.6	20.9	18.3	17.9	12.6

Table 15. Probability values from ANOVA of data from Saskatoon trial seeded in 2000.

	Establishment Year					1st Production Year				
	Companion Crop					Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield	Alfalfa	Grass	Cut 1	Cut 2	Total
	Alfalfa	Grass								
Replication	0.03	NS	NS	NA	NS	0.08	<0.01	NS	NA	NA
Companion Crop	0.02	NS	<0.01		NS	0.01	0.08	0.07		
Grass (G)	0.04	0.05	NS		NS	<0.01	<0.01	<0.01		
CC x G	0.05	NS	NS		NS	<0.01	NS	NS		
Alfalfa (A)	<0.01	NS	0.09		NS	<0.01	<0.01	<0.01		
CC x A	<0.01	NS	0.04		NS	0.02	NS	<0.01		
G x A	NS	NS	NS		NS	<0.01	NS	0.08		
CC x G x A	0.05	NS	NS		NS	<0.01	NS	NS		
c.v. (%)	22.1	23.6	19.9		17.6	42.0	48.6	32.2		

Table 16. Probability values from ANOVA of data from Swift Current trial seeded in 2000.

	Establishment Year					1st Production Year				
			Companion Crop			Plant Density		Forage Yield		
	Seedling Density		Plant Density	Seed Yield	Biomass Yield					
	Alfalfa	Grass				Alfalfa	Grass	Cut 1	Cut 2	Total
Replication	NS	NS	NS	NS	NS	NS	NS	<0.01	NA	NA
Companion Crop	NS	0.06	<0.01	<0.01	0.01	NS	<0.01	<0.01		
Grass (G)	0.01	<0.01	NS	NS	0.05	NS	<0.01	<0.01		
CC x G	0.05	NS	<0.01	NS	0.08	NS	0.05	0.03		
Alfalfa (A)	<0.01	<0.01	NS	NS	0.02	<0.01	<0.01	<0.01		
CC x A	NS	NS	NS	NS	NS	0.03	0.04	<0.01		
G x A	NS	NS	NS	NS	NS	NS	<0.01	0.06		
CC x G x A	NS	NS	NS	NS	NS	NS	NS	NS		
c.v. (%)	20.1	21.4	13.6	17.5	18.1	36.0	32.0	14.6		

Table 17. Companion crop and grass species interaction for three site-years in Saskatchewan.

Site	Year seeded	Grass	None	Canola	Pea	Ryegrass
Nipawin	1999	DWR	2770	1770	1160	1640
		1WG	3430	2160	1110	1690
		SWG	2170	1370	950	1200
				P=0.04		
Swift Current	1999	DWR	5060	2590	3270	3040
		1WG	5770	2450	3480	3940
		SWG	4340	2640	3240	3110
				P<0.01		
Swift Current	2000	DWR	1390	780	760	710
		1WG	2430	1330	1300	1500
		SWG	1500	980	900	750
				P=0.03		

Table 18. Companion crop and alfalfa cultivar interaction on forage DM year for six site-years at first harvest during 1999 to 2001 in Saskatchewan.

			Alfalfa cultivar in mixture			Interaction
Year	Site	Companion Crop	Beaver	Nitro	None	Prob.>F
1999	Saskatoon	None	5140	4630	5590	
		Canola	4000	4400	3890	
		Pea	3480	4000	3850	
		Ryegrass	3140	2830	3260	P<0.02
2000	Saskatoon	None	2530	2200	3640	
		Canola	1840	1530	1920	
		Pea	1190	990	1040	
		Ryegrass	1720	1500	1320	P<0.01
	Swift Current	None	5390	4330	5450	
		Canola	3650	2730	1290	
		Pea	3980	3040	2970	
		Ryegrass	4200	3200	2690	P<0.01
2001	Nipawin	None	5140	4630	5590	
		Canola	4000	4400	3890	
		Pea	3480	4000	3850	
		Ryegrass	3140	2830	3260	P<0.02
	Saskatoon	None	830	550	430	
		Canola	900	600	360	
		Pea	480	330	360	
		Ryegrass	690	410	390	P<0.01
	Swift Current	None	1710	1540	2060	
		Canola	1050	930	1110	
		Pea	990	970	1000	
		Ryegrass	1120	870	980	P<0.01

Table 19. Companion crop and alfalfa cultivar interaction on forage DM year for two site-years at second harvest during 1999 to 2001 in Saskatchewan.

			Alfalfa cultivar in mixture			Interaction
Year	Site	Companion Crop	Beaver	Nitro	None	Prob.>F
1999	Saskatoon	None	4010	2200	1510	
		Canola	3530	1890	1820	
		Pea	3370	1960	1450	
		Ryegrass	3150	2260	1660	P<0.01
2001	Nipawin	None	5120	3640	2960	
		Canola	4190	3130	2880	
		Pea	4970	3670	3460	
		Ryegrass	3340	3180	2400	P<0.01